(12) UK Patent Application (19) GB (11) 2 325 245 (13) A

(43) Date of A Publication 18.11.1998

(21) Application No 9810275.9

(22) Date of Filing 13.05.1998

(30) Priority Data
(31) 09127451 (32) 16.05.1997 (33) JP

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(51) INT CL^6
D06F 33/02 37/30

(52) UK CL (Edition P)
D1A ACA

(56) Documents Cited
GB 2202332 A
WPI Abstract Accession No. 96-151959 [16] & DE4431846 A1 (AKO Werke GmbH & Co) 07.09.94 WPI Abstract Accession No. 87-338534 [48] & J062243588 A (Matsushita Elec Ind KK) 24.10.87

(58) Field of Search
UK CL (Edition P) D1A ACA ACC ACD AFX
INT CL^6 D06F 33/00 33/02 37/30 39/00
Online: WPI

(54) Abstract Title

A drum-type washing machine

(57) A drum-type washing machine having a drum for receiving laundry, comprises speed detection means for detecting the revolution speed of either the drum or a motor (3) arranged to drive the drum. First calculation means are provided to calculate a first angular acceleration after the speed detection means detects predetermined revolution speeds while the motor is accelerated, and second calculation means are provided to calculate a second angular acceleration after the speed detection means detects predetemined revolution speeds while the motor is decelerating in a de-energised free-running state. Load determination means determine the load on the drum according to the first and second angular accelerations, and hence the amount of laundry within the drum can be determined.

FIG. 1

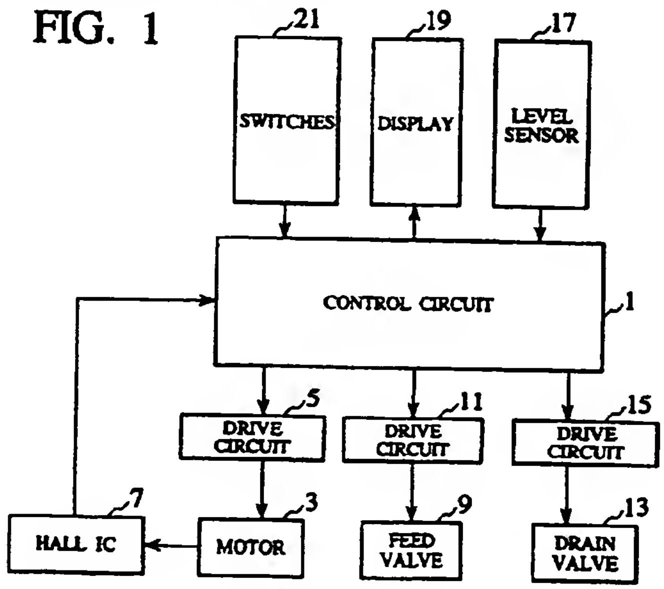

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FIG. 1

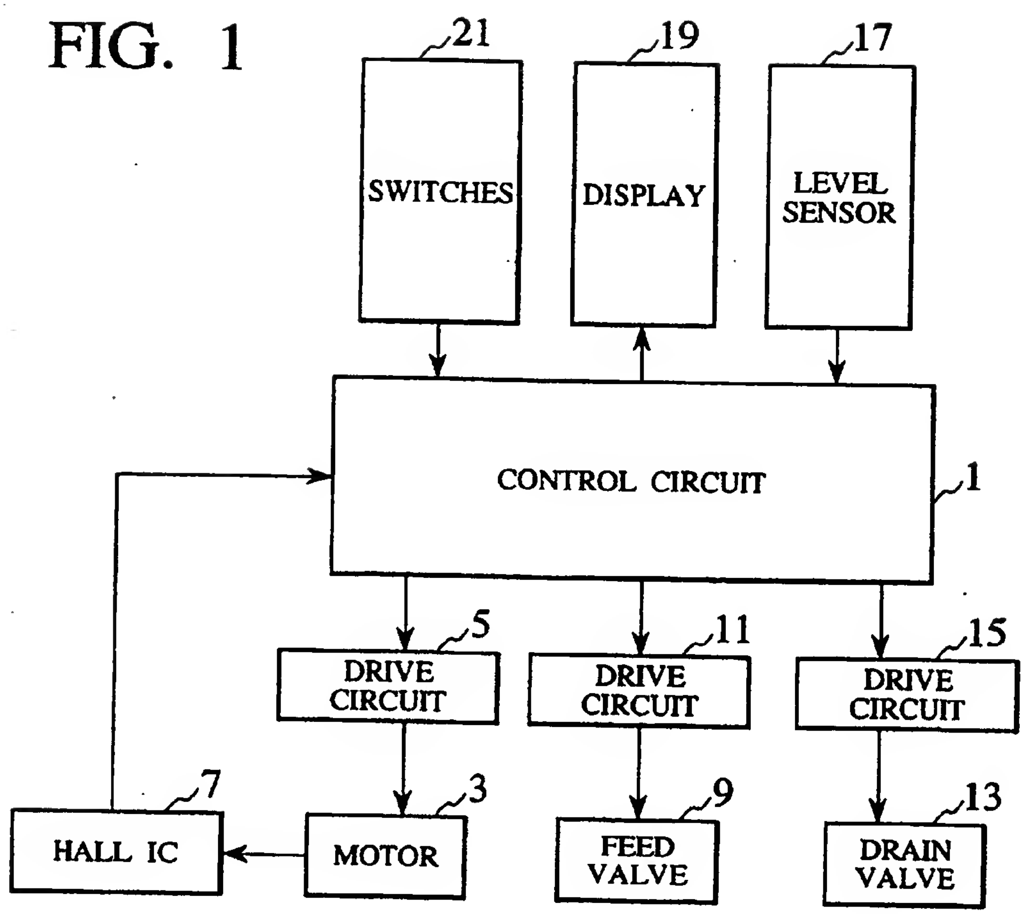

21
SWITCHES
19
DISPLAY
17
LEVEL SENSOR
CONTROL CIRCUIT
1
5
DRIVE CIRCUIT
11
DRIVE CIRCUIT
15
DRIVE CIRCUIT
7
HALL IC
3
MOTOR
9
FEED VALVE
13
DRAIN VALVE

FIG. 2

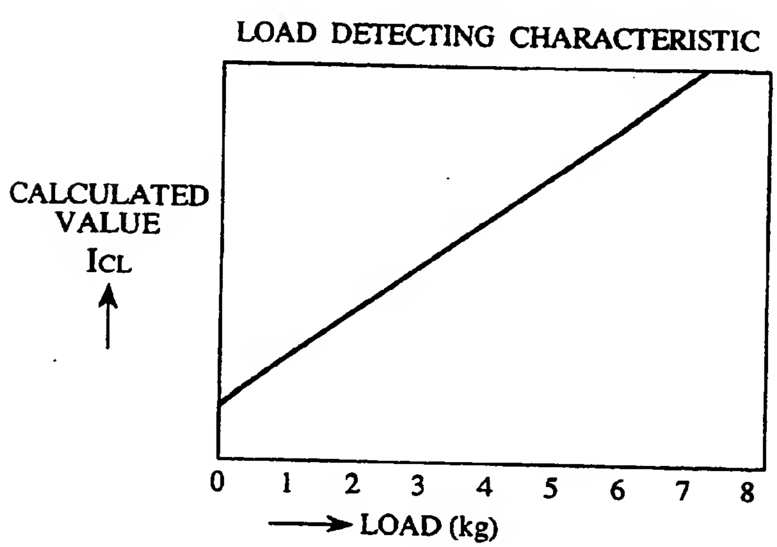

LOAD DETECTING CHARACTERISTIC
CALCULATED VALUE
I_{CL}
0 1 2 3 4 5 6 7 8
LOAD (kg)

FIG. 3

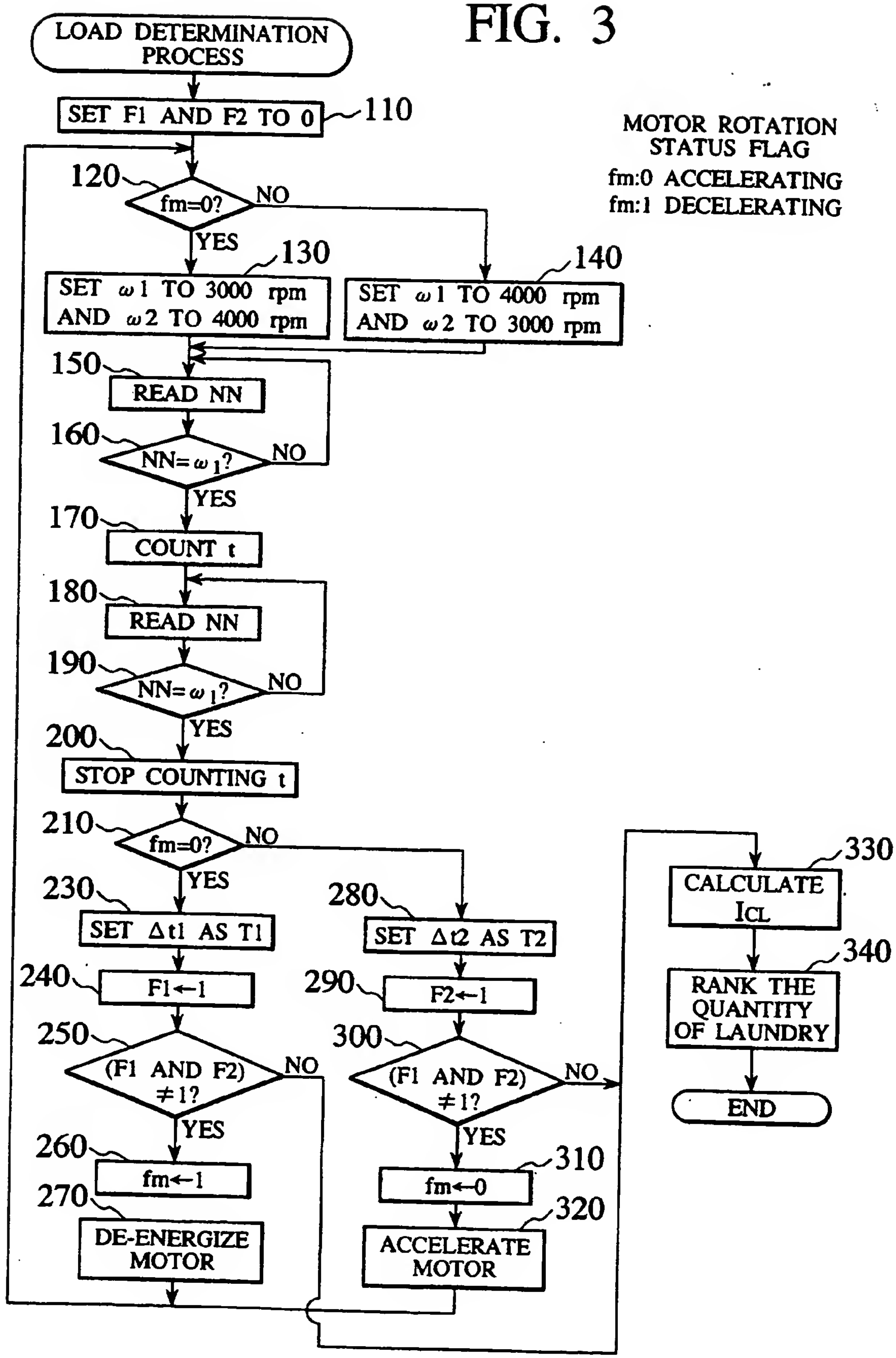

LOAD DETERMINATION PROCESS
SET F1 AND F2 TO 0
110
MOTOR ROTATION STATUS FLAG
fm:0 ACCELERATING
fm:1 DECELERATING
120
fm=0?
NO
YES
130
SET ω1 TO 3000 rpm AND ω2 TO 4000 rpm
140
SET ω1 TO 4000 rpm AND ω2 TO 3000 rpm
150
READ NN
160
NN=ω1?
NO
YES
170
COUNT t
180
READ NN
190
NN=ω1?
NO
YES
200
STOP COUNTING t
210
fm=0?
NO
YES
230
SET Δt1 AS T1
280
SET Δt2 AS T2
240
F1←1
290
F2←1
250
(F1 AND F2) ≠1?
NO
YES
300
(F1 AND F2) ≠1?
NO
YES
260
fm←1
310
fm←0
270
DE-ENERGIZE MOTOR
320
ACCELERATE MOTOR
330
CALCULATE ICL
340
RANK THE QUANTITY OF LAUNDRY
END

FIG. 4

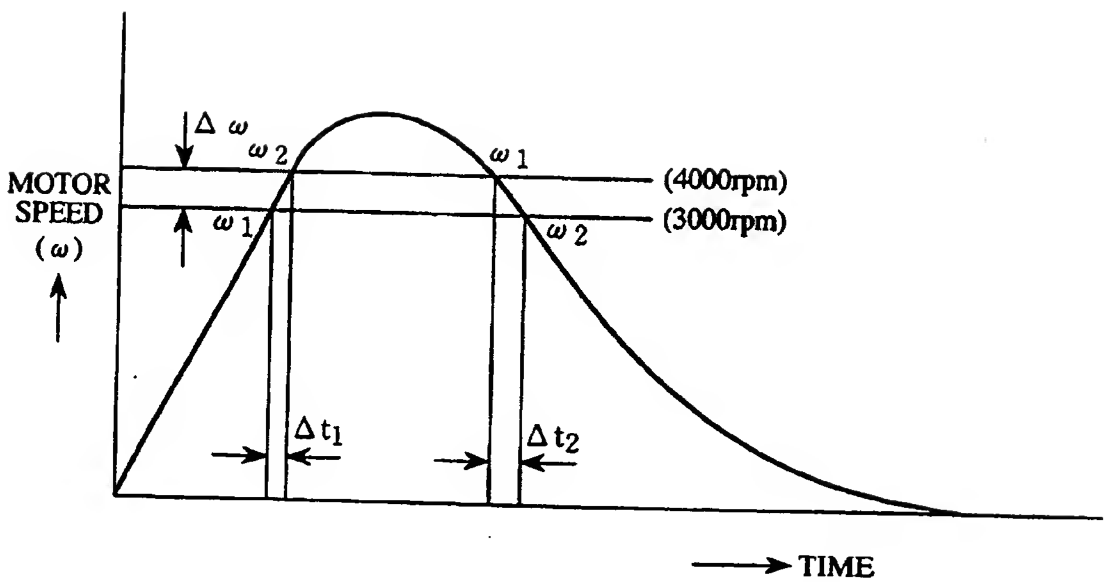


FIG. 5

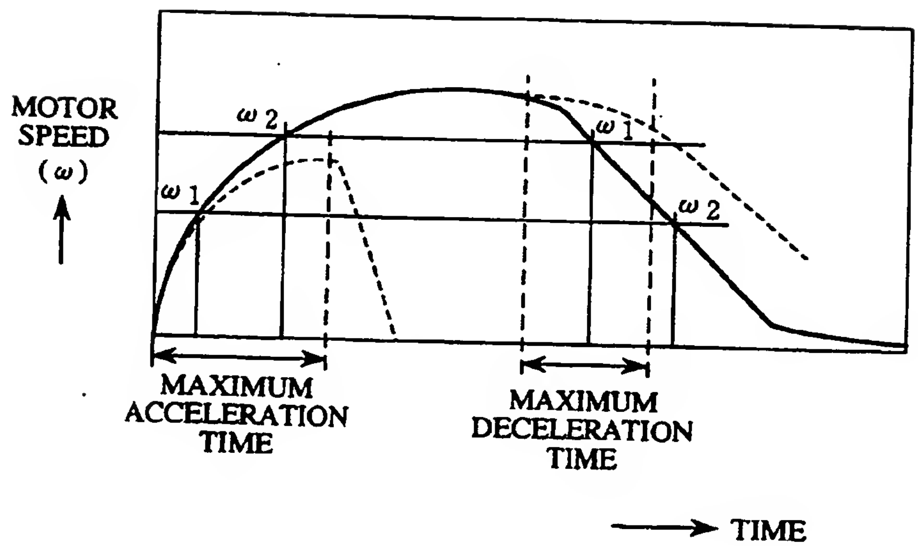

MOTOR
SPEED
(ω)
ω 2
ω 1
ω 1
ω 2
MAXIMUM
ACCELERATION
TIME
MAXIMUM
DECELERATION
TIME
TIME

FIG. 6

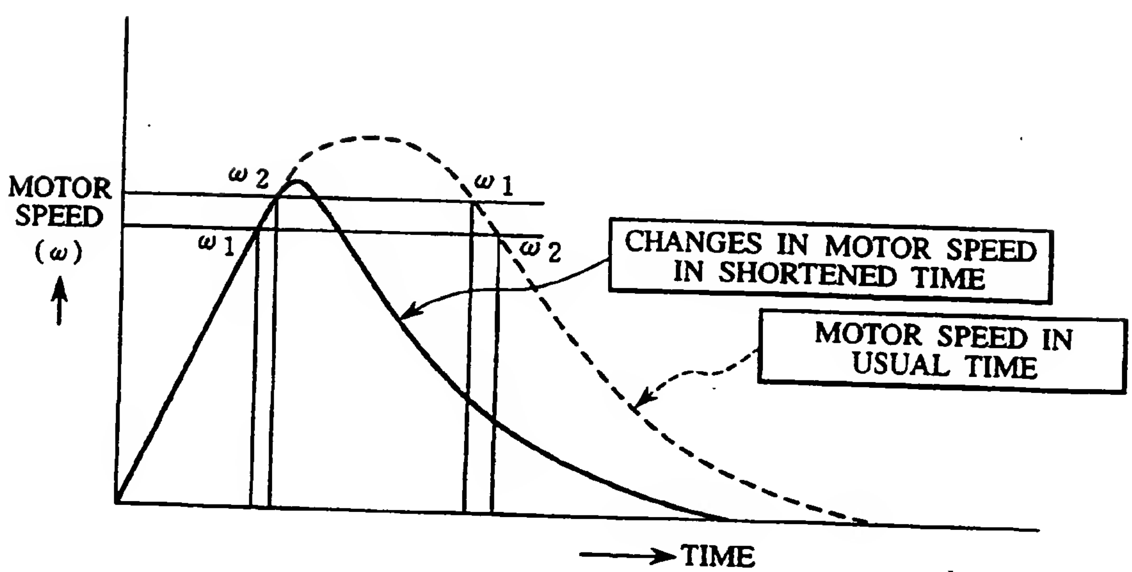

MOTOR
SPEED
(ω)
ω 2
ω 1
ω 1
ω 2
CHANGES IN MOTOR SPEED
IN SHORTENED TIME
MOTOR SPEED IN
USUAL TIME
TIME

FIG. 7

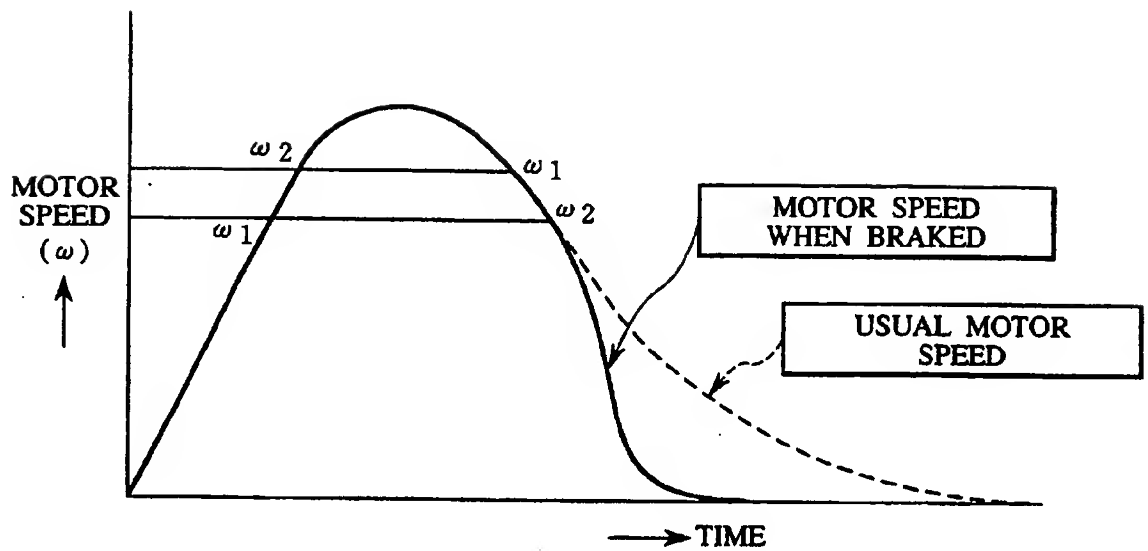

MOTOR SPEED (ω)
ω 2
ω 1
ω 1
ω 2
MOTOR SPEED WHEN BRAKED
USUAL MOTOR SPEED
TIME

FIG. 8

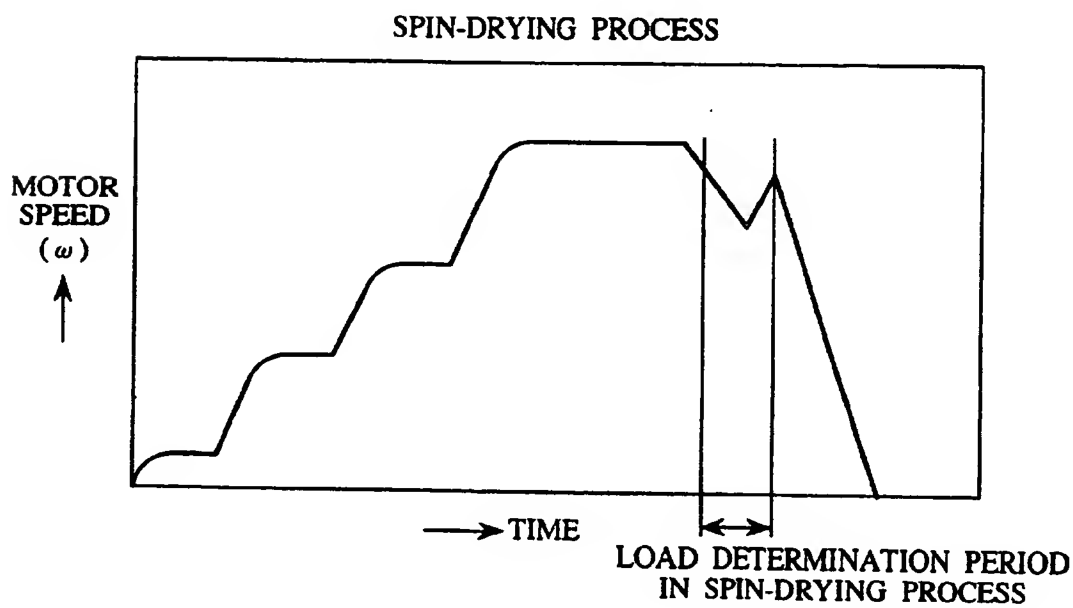

SPIN-DRYING PROCESS
MOTOR SPEED (ω)
TIME
LOAD DETERMINATION PERIOD IN SPIN-DRYING PROCESS

FIG. 9

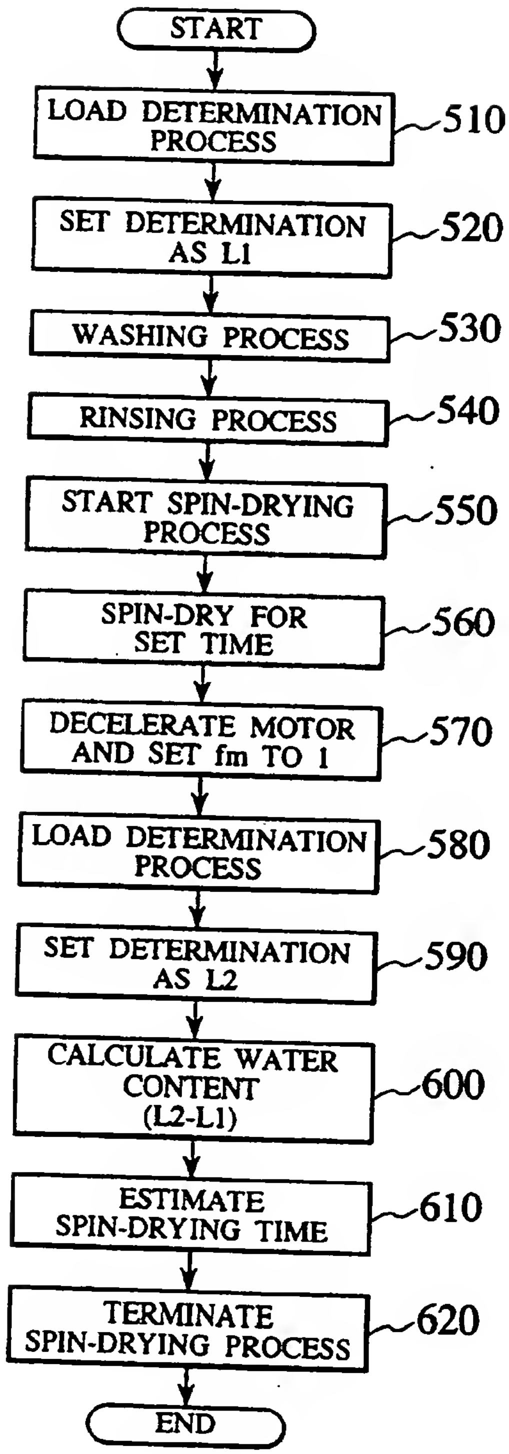
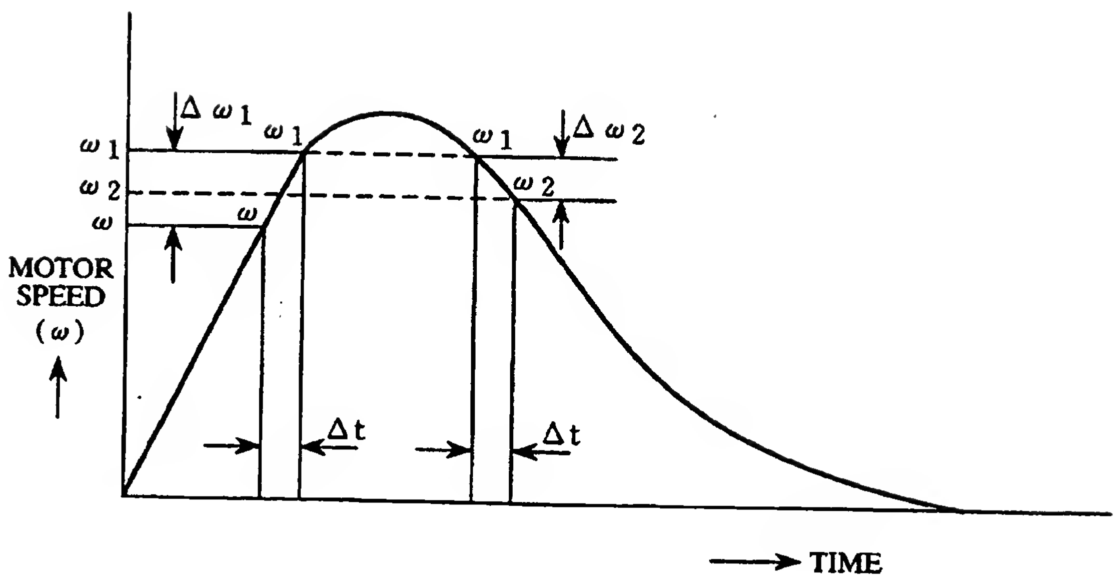

START
LOAD DETERMINATION PROCESS
510
SET DETERMINATION AS L1
520
WASHING PROCESS
530
RINSING PROCESS
540
START SPIN-DRYING PROCESS
550
SPIN-DRY FOR SET TIME
560
DECELERATE MOTOR AND SET fm TO 1
570
LOAD DETERMINATION PROCESS
580
SET DETERMINATION AS L2
590
CALCULATE WATER CONTENT (L2-L1)
600
ESTIMATE SPIN-DRYING TIME
610
TERMINATE SPIN-DRYING PROCESS
620
END

FIG. 10



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Title of the Invention

DRUM-TYPE WASHING MACHINE

Background of the Invention

1. Field of the Invention

The present invention relates to a drum-type washing machine having a drum for receiving laundry, capable of correctly measuring the quantity of the laundry, i.e., load on the drum.

2. Description of the Prior Art

Drum-type washing machines employ a drum to receive and wash laundry. Since the inertial moment of the drum is proportional to the quantity of laundry in the drum, a prior art measures the inertial moment of the drum and calculates the quantity of laundry, i.e., load on the drum.

More precisely, acceleration and deceleration of the drum are expressed with the following equations of motion on a rotational coordinate system:

$$(ICS + IB)\, d\omega/dt + k\omega^2 = T - TL \qquad \ldots(1)$$

$$(ICS + IB)\, d\omega/dt = TL + k\omega^2 \qquad \ldots(2)$$

where ICS is the inertial moment of laundry in the drum, IB is the inertial moment of the drum, ω is the angular velocity of the drum, k is the viscosity resistance coefficient of air with respect to the drum that is rotating, T is the torque of the drum, and TL is a torque loss.

The expression (1) provides the inertial moment ICS of the laundry as follows:

$$ICS = (T - TL - k\omega^2) / (d\omega/dt) - IB \qquad \ldots(3)$$

This inertial moment ICS will provide the quantity of the laundry.

The prior art employs the expression (3) to calculate the inertial moment of laundry in the drum and then the

quantity of the laundry. If the torque loss TL varies, the drum will be differently accelerated even if the quantity of laundry in the drum is fixed. If the torque loss TL increases, the calculated quantity of laundry will increase more than the actual quantity thereof, and if the torque loss TL decreases, the calculated quantity of laundry will decrease less than the actual quantity thereof.

The torque loss TL of the washing machine includes a fixed loss caused by bearings and transmission belts of the machine and a vibration loss caused by laundry unevenly distributed in the drum. The torque loss TL changes due to aging of the machine, temperature that affects the tension of the transmission belts, and an uneven distribution of laundry in the drum.

In this way, the torque loss TL always changes, and therefore, the prior art is incapable of correctly calculating the quantity of laundry in the drum.

If the quantity of laundry in the drum exceeds a rated value, or if laundry is unevenly distributed in the drum to loose a balance of load on the drum, a longer time is needed to accelerate the drum to a specified revolution speed. This results in elongating a time to calculate the quantity of laundry in the drum.

Summary of the Invention

An object of the present invention is to provide a drum-type washing machine having a drum for receiving laundry, capable of correctly measuring the quantity of laundry in the drum in a short time and washing the laundry efficiently.

In order to accomplish the object, an aspect of the present invention provides a drum-type washing machine having a drum for receiving laundry, a speed detector for detecting the revolution speed of the drum or of a motor that drives the drum, a first calculator for calculating a

first angular acceleration after the speed detector detects predetermined revolution speeds while the motor is accelerating, a second calculator for calculating a second angular acceleration after the speed detector detects the predetermined revolution speeds while the motor is decelerating in a de-energized free-running state, and a load determination unit for determining load on the drum according to the first and second angular accelerations.

This aspect calculates a first angular acceleration while accelerating the motor and a second angular acceleration while decelerating the motor in a de-energized free-running state and determines the quantity of laundry, i.e., load on the drum according to the first and second angular accelerations. Unlike the prior art, this arrangement correctly measures load on the drum without the influence of fluctuations in torque loss.

In another aspect of the present invention, the first calculator calculates the first angular acceleration according to a difference between first and second revolution speeds and an acceleration time between the instants the speed detector detects the first and second revolution speeds while the motor is accelerating. The second calculator calculates the second angular acceleration according to the difference between the first and second revolution speeds and a deceleration time between the instants the speed detector detects the second and first revolution speeds while the motor is decelerating in a de-energized free-running state.

This aspect calculates the first angular acceleration according to the difference between the first and second revolution speeds and an acceleration time taken for accelerating the motor from the first revolution speed to the second revolution speed, and the second angular acceleration according to the difference between the first and second revolution speeds and a deceleration time taken for decelerating the motor from the second revolution speed

to the first revolution speed in a de-energized free-running state.

In still another aspect of the present invention, the first calculator calculates the first angular acceleration according to a change in revolution speed in a predetermined time starting when the speed detector detects a first revolution speed while the motor is accelerating, and the second calculator calculates the second angular acceleration according to a change in revolution speed in the predetermined time starting when the speed detector detects a second revolution speed while the motor is decelerating in a de-energized free-running state.

This aspect calculates the first angular acceleration according to a change in revolution speed in a predetermined time starting when the speed detector detects a first revolution speed while the motor is accelerating, and the second angular acceleration according to a change in revolution speed in the predetermined time starting when the speed detector detects a second revolution speed while the motor is decelerating in a de-energized free-running state.

In still another aspect of the present invention, the washing machine has an alarm unit for providing an alarm if the speed detector does not detect a first revolution speed within a specified time after detecting a second revolution speed while the motor is decelerating in a de-energized free-running state.

This aspect issues an alarm if the motor does not decelerate from a second revolution speed to a first revolution speed within a specified time while the motor is decelerating in a de-energized free-running state, so that the user may recognize that the quantity of laundry is excessive.

In still another aspect of the present invention, the washing machine has an alarm unit for providing an alarm if the speed detector does not detect a second revolution

speed within a specified time after detecting a first revolution speed while the motor is accelerating.

This aspect issues an alarm if the motor is not accelerated from a first revolution speed to a second revolution speed within a specified time, so that the user may recognize that the quantity of laundry is excessive.

In still another aspect of the present invention, the washing machine has a water feeder for feeding water into the drum after the load determination unit determines, before the start of a washing process, load on the drum and before the drum stops to rotate.

This aspect determines load on the drum before starting a washing process and feeds water into the drum before the drum stops to rotate, thereby quickening the start of the washing process.

In still another aspect of the present invention, the washing machine has a water feeder for feeding water into the drum if a load determined by the load determination unit is less than a specified value.

This aspect feeds water into the drum if load on the drum is less than a specified value, to properly wash laundry.

In still another aspect of the present invention, the washing machine has a decelerator for de-energizing the motor and decelerating the drum into a free-running state as soon as the first calculator calculates the first angular acceleration.

This aspect de-energizes the motor to decelerate the drum into a free-running state just after calculating the first angular acceleration, thereby shortening a time for determining load on the drum.

In still another aspect of the present invention, the washing machine has a brake for forcibly stopping the rotation of the motor, which has been de-energized to decelerate the drum into a free-running state, if the speed detector detects a revolution speed below a specified value

or if a specified time elapses after de-energizing the motor.

This aspect forcibly stops the rotation of the motor if a detected revolution speed is below a specified value or if a specified time elapses after de-energizing the motor, thereby shortening a washing time.

In another aspect of the present invention, there is provided a drum-type washing machine having a drum for receiving laundry, a first determination unit for determining a first load on the drum before starting a washing process, a second determination unit for determining a second load on the drum a predetermined time after the start of a spin-drying process, a calculator for calculating a water content of the laundry in the drum according to the first and second loads, and an estimation unit for estimating a spin-drying time according to the water content.

This aspect calculates a water content of laundry according to a load determined before a washing process and a load determined a predetermined time after the start of a spin-drying process and estimates a spin-drying time according to the water content, so that the user may know the time when the spin-drying process ends.

In still another aspect of the present invention, there is provided a drum-type washing machine having a drum for receiving laundry, a first determination unit for determining a first load on the drum before starting a washing process, a second determination unit for determining a second load on the drum during a spin-drying process, and a changer for changing a spin-drying time according to the first and second loads.

This aspect changes a spin-drying time according to a load determined before starting a washing process and a load determined during a spin-drying process, to uniformly spin-dry laundry in an optimum time without the influence of the material of the laundry and water temperature.

In still another aspect of the present invention, the washing machine has a determination controller for controlling the second determination unit to repeatedly determine load on the drum during a spin-drying process, and a time controller for controlling a spin-drying time according to each load determined by the second determination unit, to attain a predetermined dryness ratio.

This aspect repeatedly determines load on the drum during a spin-drying process and controls a spin-drying time according to each determined load, to attain a predetermined dryness ratio. This aspect is capable of uniformly spin-drying laundry within an optimum time without the influence of the material of laundry and water temperature.

In still another aspect of the present invention, the washing machine has a dryness setter for setting a dryness ratio and a time adjuster for adjusting a spin-drying time according to each load determined by the second determination unit, to attain the set dryness ratio.

This aspect sets a required dryness ratio and adjusts a spin-drying time according to repeatedly determined loads, to attain the set dryness ratio. This aspect is capable of spin-drying laundry to a dryness ratio set by the user.

Brief Description of the Drawings

These and other objects, features, aspects, and advantages of the present invention will become more apparent from the following detailed description of the present invention when taken in conjunction with the accompanying drawings, in which:

Fig. 1 is a block diagram showing a control system of a drum-type washing machine according to an embodiment of the present invention;

Fig. 2 is a graph showing a relationship between the inertial moment of laundry and the quantity thereof;

Fig. 3 is a flowchart showing the operation of the washing machine of Fig. 1;

Fig. 4 is a graph showing temporal changes in motor speed when calculating angular accelerations during the acceleration and deceleration of a motor of the washing machine;

Fig. 5 is a graph showing temporal changes in motor speed with the washing machine containing excessive laundry;

Fig. 6 is a graph showing temporal changes in motor speed with a shortened time for determining load;

Fig. 7 is a graph showing temporal changes in motor speed with a time for determining load shortened by braking;

Fig. 8 is a graph showing temporal changes in motor speed when determining load during a spin-drying process;

Fig. 9 is a flowchart showing a process of estimating a spin-drying time; and

Fig. 10 is a graph showing temporal changes in motor speed when calculating angular accelerations during the acceleration and deceleration of the motor of the washing machine.

Detailed Description of the Embodiments

A drum-type washing machine according to a preferred embodiment of the present invention will be explained with reference to the accompanying drawings.

Figure 1 is a block diagram showing a control system of a drum-type washing machine according to a preferred embodiment of the present invention. Elements of the control system will be explained. A control circuit 1 controls the other elements. A motor 3 drives a drum (not shown) for receiving laundry. A drive circuit 5 drives the

motor 3 under the control of the control circuit 1. A Hall IC 7 detects the revolution speed of the motor 3 and supplies the detected value to the control circuit 1. A feed valve 9 controls the supply of water to the drum. A drive circuit 11 drives the feed valve 9 under the control of the control circuit 1. A drain valve 13 controls the drainage of water from the drum. A drive circuit 15 drives the drain valve 13 under the control of the control circuit 1. A water level sensor 17 detects the level of water in the drum. A display 19 displays various kinds of information such as alarm information. Switches 21 include a power source switch and a start switch.

To eliminate the influence of the torque loss explained in connection with the prior art, the present invention calculates the inertial moment ICL of laundry of the expressions (1) and (2) by setting an angular acceleration $d\omega/dt$ related to accelerating of the drum (or the motor 3) as $(d\omega/dt)s$ and an angular acceleration $d\omega/dt$ related to deceleration of the drum as $(d\omega/dt)e$ with substantially the same angular velocity ω for acceleration and deceleration of the drum. Consequently, the present invention expresses the inertial moment ICL of laundry as follows:

$$ICL = \frac{T}{2((d\omega/dt)s + (d\omega/dt)e)} + \frac{IB}{2} \qquad \ldots(4)$$

This eliminates the torque loss TL that causes an error in the prior art.

The present invention finds an angular acceleration S1 (= $(d\omega/dt)s$) when accelerating the drum (or the motor 3 that drives the drum) as well as an angular acceleration S2 (= $(d\omega/dt)e$) when decelerating the drum and correctly calculates the inertial moment ICL of laundry according to the expression (4). The present invention then finds the quantity of the laundry, i.e., load on the drum according to a load detecting characteristic of Fig. 2.

The operation of the control system of Fig. 1 will be

explained with reference to a flowchart of Fig. 3.

The user puts laundry in the drum of the washing machine and manipulates the start switch among the switches 21. Before feeding water into the drum, the control system detects the quantity of the laundry, i.e., load on the drum according to the flowchart of Fig. 3, and based on the load, carries out washing, rinsing, and spin-drying processes.

In Fig. 3, step 110 initializes an acceleration time flag F1 and a deceleration time flag F2 to 0. Step 120 checks to see if a motor rotation status flag fm for the motor 3 is 0.

The flag fm is 0 if the motor 3 is accelerating, and 1 if it is decelerating.

If fm = 0, step 130 sets revolution speeds $\omega 1$ and $\omega 2$ to 3000 rpm and 4000 rpm, respectively.

Figure 4 is a graph showing temporal changes in the revolution speed of the motor 3. The speeds $\omega 1$ = 3000 rpm and $\omega 2$ = 4000 rpm are shown in an accelerating section of the graph.

Step 150 reads a revolution speed NN of the motor 3. Step 160 checks to see if NN = $\omega 1$ (3000 rpm).

If NN = $\omega 1$ (3000 rpm), step 170 starts to count time until the motor 3 reaches $\omega 2$ (4000 rpm). Step 180 again reads NN, and step 190 checks to see if NN = $\omega 2$ (4000 rpm).

If NN = $\omega 2$ (4000 rpm), step 200 stops counting time and calculates a time $\Delta t1$ taken to accelerate the motor 3 from $\omega 1$ to $\omega 2$.

Step 210 checks to see if the motor rotation status flag fm is 0 and determines whether or not the motor 3 is accelerating. Since fm = 0 at this moment, step 230 sets the time $\Delta t1$ as an acceleration time T1. Step 240 sets the acceleration time flag F1 to 1 to indicate that the acceleration time has been determined.

Step 250 checks to see if both the acceleration and

deceleration time flags F1 and F2 are 1. Since the deceleration flag F2 is still 0 at this moment, step 260 sets the motor rotation status flag fm to 1, and step 270 de-energizes the motor 3 to put the drum in a free-running state. The flow returns to step 120.

The motor 3 starts to decelerate as shown in Fig. 4. Step 120 checks to see if fm = 0.

Since fm = 1 with the motor 3 decelerating, step 140 sets revolution speeds $\omega 1$ and $\omega 2$ to 4000 rpm and 3000 rpm, respectively.

Step 150 reads a revolution speed NN of the motor 3, and step 160 checks to see if NN = $\omega 1$ (4000 rpm).

If NN = $\omega 1$ (4000 rpm), step 170 starts to count time until the motor 3 reaches $\omega 2$ (3000 rpm).

Step 180 again reads NN, and step 190 checks to see if NN = $\omega 2$ (3000 rpm). If NN = $\omega 2$ (3000 rpm), step 200 stops counting time and calculates a time $\Delta t2$ taken to decelerate the motor 3 from $\omega 1$ to $\omega 2$.

Step 210 checks to see if the motor rotation status flag fm is 0. Since fm = 1 with the motor 3 decelerating, step 280 sets the time $\Delta t2$ as a deceleration time T2. Step 290 sets the deceleration time flag F2 to 1 to indicate that the deceleration time has been determined.

Step 300 checks to see if both the acceleration and deceleration time flags F1 and F2 are 1. Since they are each 1, step 330 calculates the inertial moment ICL of the laundry according to the expression (4).

As shown in Fig. 4, the first angular acceleration S1 (= $(d\omega/dt)s$) is calculated according to the acceleration time $\Delta t1$ and difference $\Delta \omega$ (= $\omega 1 - \omega 2$) between the revolution speeds $\omega 1$ (3000 rpm) and $\omega 2$ (4000 rpm) for acceleration of the motor 3. The second angular acceleration S2 (= $(d\omega/dt)e$) is calculated according to the time $\Delta t2$ and difference $\Delta \omega$ (= $\omega 1 - \omega 2$) between the revolution speeds $\omega 1$ (4000 rpm) and $\omega 2$ (3000 rpm) for deceleration of the motor 3. From these S1 and S2, the

inertial moment ICL of the laundry is calculated according to the expression (4).

According to the inertial moment ICL and the load detecting characteristic of Fig. 2, the quantity of the laundry, i.e., load on the drum is found. Then, step 340 finds a weight rank for the laundry to carry out washing, rinsing, and spin-drying processes.

If the time Δ t1 for accelerating the motor 3 from ω 1 (3000 rpm) to ω 2 (4000 rpm) is longer than a specific time Δ ts, the quantity of the laundry will be excessive. In this case, the present invention may stop the rotation of the drum as shown in Fig. 5, issue an alarm for the user through the display 19, and sound a buzzer.

If the time Δ t2 for decelerating the motor 3 from ω 1 (4000 rpm) to ω 2 (3000 rpm) is longer than a specific time Δ te, the quantity of the laundry will be excessive. In this case, the present invention may stop the rotation of the drum as shown in Fig. 5, issue an alarm for the user through the display 19, and sound a buzzer.

In Fig. 6, the present invention de-energizes the motor 3 as soon as the motor 3 accelerates to ω 2 (4000 rpm) to make the motor 3 decelerate as indicated with a continuous line. This technique shortens a load determination time.

In Fig. 7, the present invention drives the feed valve 9 when the motor 3 decelerates to 3000 rpm, to feed water into the drum. At the same time, a brake (not shown) is activated to stop the rotation of the drum. When water is fed up to a specified level, a washing process starts.

The brake may be an electromagnetic brake that short-circuits a motor coil to brake the motor 3. When the motor 3 decelerates to 3000 rpm, the brake is activated to quickly stop the rotation of the motor 3, to thereby shorten a load determination time.

The brake may be a mechanical brake. Instead of being dependent on the speed of the motor 3, the braking may be

executed a predetermined time after the start of deceleration.

The present invention starts feeding water into the drum while the drum is decelerating. This results in quickly starting the washing process and shortening the total operation time of the washing machine.

In Fig. 8, the present invention again detects the quantity of the laundry during the spin-drying process that follows the washing and rinsing processes. The detected quantity of the wet laundry is compared with the quantity of the dry laundry detected before the washing process, to calculate the water content of the laundry, i.e., the dryness ratio of the laundry.

In this way, the present invention may detect the dryness ratio of laundry during the spin-drying process. Generally, a spin-drying time is set to 10 minutes to realize a dryness ratio of 55%. An actual dryness ratio, however, greatly fluctuates depending on the kind and quantity of laundry and water temperature.

The load determination process for finding a dryness ratio may be carried out, for example, three minutes after the start of the spin-drying process. The quantity of laundry detected thereby is the sum of the quantity of dry laundry and water contained in the laundry. According to this detected quantity and the quantity detected before the washing process, a dryness ratio is calculated.

Table 1 shows an experimentally obtained relationship between a dryness ratio after three minutes of the spin-drying process and a remaining spin-drying time to provide a dryness ratio of 55%. The control circuit 1 determines a remaining spin-drying time based on this table.

Table 1

Dryness after 3 min.	Remaining spin-drying time
48% or below	8 min.
48% to 52%	5 min.
52% to 55%	2 min.
55% or above	0 min.

If the dry weight of laundry is 3 kg and the weight thereof after three minutes of the spin-drying process is 6.3 kg, the dryness ratio of the laundry is 48%. Then, a remaining spin-drying time of 8 minutes is obtained from Table 1. If the dry weight of laundry is 3 kg and the weight thereof after three minutes of the spin-drying process is 5.8 kg, the dryness ratio of the laundry is 51.5%. Then, it is understood that the laundry is of synthetic fiber that is easy to dry. In this case, a short spin-drying time is sufficient, and a remaining spin-drying time of 5 minutes is selected from Table 1. In this way, the control circuit 1 changes a spin-drying time according to a result of the load determination process carried out during the spin-drying process, to thereby optimize the spin-drying process. Table 1 may have more precisely ranked data instead of the four-rank data shown.

Instead of employing such a data table, it is possible to extend the spin-drying time by a specific time of , for example, one minute whenever it is determined that the dryness ratio of laundry is below the target dryness ratio of 55% during the spin-drying process. In this case, the load determination process is repeated. Namely, the load determination process and an extension of spin-drying time are alternated during the spin-drying process, to attain the target dryness ratio.

In this way, the present invention automatically controls the spin-drying time of laundry according to a result of the load determination process carried out during

the spin-drying process, to optimize the spin-drying process without the influence of the material of the laundry and water temperature and without much reference data.

The washing machine of the present invention may have a function of letting the user select, for example, a weak spin-drying course for laundry that must be weakly spin-dried or a strong spin-drying course for laundry that must be strongly spin-dried. The weak spin-drying course sets a dryness ratio of, for example, 50%, and the strong spin-drying course sets a dryness ratio of, for example, 60%. The control circuit 1 repeats the load determination process during a spin-drying process and changes a spin-drying time accordingly, to thereby achieve the dryness ratio of the selected spin-drying course.

The washing machine of the present invention may have a unit for letting the user set a dryness ratio according to the material of laundry. To attain the set dryness ratio, the control circuit 1 controls a spin-drying time.

The washing machine of the present invention may have a dryer function. In this case, the control circuit 1 carries out the load determination process upon the completion of a spin-drying process, to find the quantity of laundry and the quantity of water to be dried. According to the data, the control circuit 1 estimates a dryer time and displays the same or an estimated completion time.

This operation will be explained with reference to a flowchart of Fig. 9.

Step 510 carries out the load determination process before starting a washing process, and step 520 sets a result of the load determination process as a load L1, which corresponds to the quantity of laundry that is dry before washing.

Step 530 carries out the washing process, and step 540 carries out a rinsing process. Step 550 starts a spin-

drying process.

Step 560 continues the spin-drying process for a predetermined time. Step 570 decelerates the motor 3 and sets a motor rotation status flag fm to 1.

Step 580 carries out the load determination process. Step 590 sets a result of the load determination process as a load L2. Step 600 calculates "L2 - L1" to provide the quantity of water contained in the laundry. Step 610 sets an estimated dryer time according to the water quantity. Step 620 displays the estimated dryer time on the display 19, carries out a dryer process, and terminates the dryer process after the estimated dryer time.

The dryer capacity of a washing machine is usually half the washing capacity thereof. If a course of washing, rinsing, spin-drying, and drying is selected by the user and if the load determination process determines that the quantity of laundry is greater than the dryer capacity, excessive part of the laundry must be taken out. In this case, no water is fed after the load determination process. If the quantity of laundry is less than the dryer capacity, water is fed into the drum after the load determination process and before the drum stops to rotate.

In Fig. 3, steps 130 to 280 calculate angular accelerations during acceleration and deceleration of the motor 3 according to an acceleration time Δ t1 for accelerating the motor 3 from 3000 rpm to 4000 rpm and a deceleration time Δ t2 for decelerating the motor 3 from 4000 rpm to 3000 rpm. Instead, the angular accelerations may be calculated according to changes in angular speed in a specific time, as shown in Fig. 10.

In Fig. 10, counting time starts when the motor 3 is accelerated to a revolution speed ω of 3000 rpm. After a predetermined time Δ t, the revolution speed of the motor 3 is measured as ω 1, and a speed change $\Delta \omega$ s (= ω 1 - ω) in the time Δ t is calculated. Then, the motor 3 is decelerated. When the motor 3 decelerates to ω 1, counting

time starts. After the time Δt, the revolution speed of the motor 3 is measured as $\omega 2$, and a speed change $\Delta \omega e$ (= $\omega 1 - \omega 2$) in the time Δt is calculated. According to the speed changes $\Delta \omega s$ and $\Delta \omega e$, angular accelerations for acceleration and deceleration of the motor 3 are calculated and used to find the inertial moment ICL of laundry according to the expression (4). Thereafter, the quantity of laundry, i.e., load on the drum is found on the load detecting characteristic of Fig. 2.

Although the above embodiment uses the revolution speed of the motor 3 to calculate load on the drum and the quantity of laundry, the present invention is not limited to this. For example, the revolution speed of the drum driven by the motor 3 may be used for the same purpose. Any other parameter that is proportional to the revolution speed of the motor 3 may be used by the present invention for the same purpose.

In summary, the washing machine of the present invention calculates a first angular acceleration while accelerating the motor and a second angular acceleration while decelerating the motor in a free-running state with the motor 3 de-energized, and determines the quantity of laundry, i.e., load on the drum according to the first and second angular accelerations. Unlike the prior art, this technique correctly measures load on the drum without the influence of fluctuations in torque loss.

The washing machine of the present invention issues an alarm if the motor 3, which has been de-energized to decelerate the drum into a free-running state, does not decelerate from a second revolution speed to a first revolution speed within a specified time, so that the user may recognize that the quantity of the laundry is excessive and may properly wash laundry.

The washing machine of the present invention determines load on the drum before starting a washing process and feeds water into the drum before the drum stops

to rotate, thereby quickening the start of the washing process.

The washing machine of the present invention feeds water into the drum if load on the drum is less than a specified value, to properly wash laundry.

The washing machine of the present invention de-energizes the motor to decelerate the drum into a free-running state just after a first angular acceleration is calculated, thereby shortening a time for determining load on the drum.

The washing machine of the present invention forcibly stops the rotation of the motor 3 if the motor 3 decelerates below a specified revolution speed or if a specified time elapses after de-energizing the motor 3, thereby shortening a washing time.

The washing machine of the present invention calculates a water content of laundry according to a load determined before a washing process and a load determined a predetermined time after the start of a spin-drying process and estimates a spin-drying time according to the water content, so that the user may know the time when the spin-drying process ends.

The washing machine of the present invention changes a spin-drying time according to a load determined before a washing process and a load determined during a spin-drying process, to uniformly spin-dry laundry in an optimum time without the influence of the material of the laundry and water temperature.

The washing machine of the present invention repeatedly determines load on the drum during a spin-drying process and controls a spin-drying time according to each determined load, to attain a predetermined dryness ratio. This technique is capable of uniformly spin-drying laundry within an optimum time without the influence of the material of the laundry and water temperature.

The washing machine of the present invention sets a

required dryness ratio and adjusts a spin-drying time according to repeatedly determined loads, to attain the set dryness ratio. This aspect is capable of spin-drying laundry according to a dryness ratio set by the user.

While the above provides a full and complete disclosure of the preferred embodiments of the present invention, various modifications, alternate constructions, and equivalents may be employed without departing from the scope of the invention. Therefore, the above description and illustration should not be construed as limiting the scope of the invention, which is defined by the appended claims.

CLAIMS

1. A drum-type washing machine having a drum for receiving laundry, comprising:

speed detection means for detecting the revolution speed of one of the drum and a motor arranged to drive the drum;

first calculation means for calculating a first angular acceleration after the speed detection means detects predetermined revolution speeds while the motor is accelerating;

second calculation means for calculating a second angular acceleration after the speed detection means detects the predetermined revolution speeds while the motor is decelerating in a de-energised free-running state; and

load determination means for determining load on the drum according to the first and second angular accelerations.

2. The washing machine of Claim 1, wherein:

the first calculation means is arranged to calculate the first angular acceleration according to a difference between first and second revolution speeds and an acceleration time between the instants at which, in operation of the washing machine, the speed detection means detects the first and second revolution speeds while the motor is accelerating; and

the second calculation means is arranged to calculate the second angular acceleration according to the difference between the first and second revolution speeds and a deceleration time between the instants at which, in operation of the washing machine, the speed detection means detects the second and first revolution speeds while the motor is decelerating in a de-energised free-running state.

3. The washing machine of claim 1, wherein:

the first calculation means is arranged to calculate the first angular acceleration according to a change in revolution speed in a predetermined time starting when, in operation of the washing machine, the speed detection means detects a first revolution speed while the motor is accelerating; and

the second calculation means is arranged to calculate the second angular acceleration according to a change in revolution speed in the predetermined time starting when, in operation of the washing machine, the speed detection means detects a second revolution speed while the motor is decelerating in a de-energised free-running state.

4. The washing machine of either one of claims 2 and 3, further comprising:

alarm means for providing an alarm if, in operation of the washing machine, the speed detection means does not detect the first revolution speed within a specified time after detecting the second revolution speed while the motor is decelerating in a de-energised free-running state.

5. The washing machine of any one of claims 2, 3 and 4, further comprising:

alarm means for providing an alarm if, in operation of the washing machine, the speed detection means does not detect the second revolution speed within a specified time after detecting the first revolution speed while the motor is accelerating.

6. The washing machine of any preceding claim, further comprising:

water feed means for feeding water into the drum after, in operation of the washing machine, the load determination means determines, before the start of a washing process, load on the drum and before the drum stops to rotate.

7. The washing machine of claim 1, further comprising:

water feed means for feeding water into the drum if, in operation of the washing machine, the load determined by the load determination means is less than a specified value.

8. The washing machine of any preceding claim, further comprising:

deceleration means for de-energising the motor and decelerating the drum into a free-running state as soon as, in operation of the washing machine, the first calculation means calculates the first angular acceleration.

9. The washing machine of any one of claims 1 to 7, further comprising:

brake means for forcibly stopping the rotation of the motor, which has been de-energised to decelerate the drum into a free-running state if, in operation of the washing machine, the speed detection means detects a revolution speed below a specified value or if a specified time elapses after de-energising the motor.

10. A drum-type washing machine having a drum for receiving laundry, comprising:

first determination means for determining a first load on the drum before starting a washing process;

second determination means for determining a second load on the drum a predetermined time after the start of a spin-drying process;

calculation means for calculating a water content of the laundry according to the first and second loads; and

estimation means for estimating a spin-drying time according to the water content.

11. A drum-type washing machine having a drum for receiving laundry, comprising:

first determination means for determining a first load on the drum before starting a washing process;

second determination means for determining a second load on the drum during a spin-drying process; and

change means for changing a spin-drying time according to the first and second loads.

12. The washing machine of claim 11, further comprising:

determination control means for controlling the second determination means to repeatedly determine load on the drum during the spin-drying process; and

time control means for controlling a spin-drying time according to each load determined by the second determination means, to attain a predetermined dryness ratio.

13. The washing machine of claim 12, further comprising:

dryness setting means for setting a dryness ratio; and

time adjusting means for adjusting a spin-drying time according to each load determined by the second determination means, to attain the set dryness ratio.

14. A drum-type washing machine substantially as hereinbefore described with reference to the accompanying drawings.

The Patent Office

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Application No: GB 9810275.9
Claims searched: 1-9 and 14

Examiner: Caroline Marshall
Date of search: 10 June 1998

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.P): D1A (ACA, ACC, ACD, AFX)

Int Cl (Ed.6): D06F 33/00, 33/02, 37/30, 39/00.

Other: Online: WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
A	GB 2 202 332 A Kabushiki... - see whole document.	-
A	WPI Abstract Accession No. 96-151959 [16] & DE4431846 A1 (AKO Werke GmbH & Co) 07.09.94 - see abstract.	-
X	WPI Abstract Accession No. 87-338534 [48] & J062243588 A (Matushita Elec Ind KK) 24.10.87 - see abstract.	1

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